SPIN INJECTION DEVICE, MAGNETIC DEVICE USING THE SAME, MAGNETIC THIN FILM USED IN THE SAME

TECHNICAL FIELD

[0001] The present invention relates to a functional device controlling electronic spin, especially a spin injection device to make possible the magnetization reversal by spin injection with lower current density and to be utilized for ultra-gigabit large capacity, high speed, non-volatile magnetic memory, spin injection magnetic apparatus using the same, and spin injection magnetic memory device.

[0002] The present invention relates also to a magnetic thin film of large spin polarizability, and a magnetoresistance effect device and a magnetic device using the same.

BACKGROUND ART

[0003] In recent years, giant magnetoresistance (GMR) effect devices consisting of ferromagnetic layer/nonmagnetic metal layer/ferromagnetic layer and ferromagnetic spin tunnel junction (MTJ) devices consisting of ferromagnetic layer/insulating layer/ferromagnetic layer have been developed, and are expected for application to new magnetic field sensors and magnetic memories (MRAM).

[0004] GMR can bring about giant magnetoresistance effect by controlling magnetization of two ferromagnetic layers mutually parallel or antiparallel by external magnetic field, due to the fact that resistances differ from each other by spin dependent scattering at an interface. On the other hand, MTJ can bring about so-called tunnel magnetoresistance (TMR) effect, such that the magnitudes of tunnel currents in the direction perpendicular to layer surface differ from each other by controlling magnetization of two ferromagnetic layers mutually parallel or antiparallel by external magnetic field (Refer, for example, to T. Miyazaki and N. Tezuka, "Spin polarized tunneling in ferromagnet/insulator/ferromagnet junctions", (1995), J. Magn. Magn. Mater., L39, p. 1231).

[0005] Tunnel magnetoresistance TMR depends upon spin polarizability P at the interface of the ferromagnet and the insulator that are used, and is known to be expressed in general by Equation (1), assuming the spin polarizabilities of two ferromagnets as P_1 and P_2, respectively.

$$TMR=2P_1P_2/(1-P_1P_2) \quad (1),$$

where spin polarizability P of a ferromagnet has a value $0<P\leqq 1$. The highest tunnel magnetoresistance TMR at room temperature so far obtained is about 50% in case of CoFe alloy of P~0.5.

[0006] GMR devices are already in practical use for magnetic heads of hard discs. MTJ devices are presently expected for application to magnetic heads of hard discs and non-volatile magnetic memories (MRAM). In MRAM, "1" and "0" are recorded by controlling two magnetic layers mutually parallel and antiparallel which make up each MTJ device by arranging MTJ devices in matrix, and applying magnetic field by flowing electric current in the interconnection provided separately. The readout is conducted utilizing TMR effect. However, MRAM has such a problem to be solved that, when a device size is made small for large capacity, the electric current needed for magnetization reversal increases due to the increase of demagnetizing field, thereby the power consumption increases.

[0007] As a method to solve such a problem, the triple layer structure is proposed in which two magnetic layers combined mutually antiparallel via nonmagnetic metal layer (Synthetic Antiferromagnet, hereinafter referred to as "SyAF". Refer, for example, to the Japanese Patent Laid Application H9-251621A (1997)). By using such SyAF structure, the magnetic field needed for magnetization reversal is reduced even if a device size is made small, because of decrease of demagnetizing field.

[0008] On the other hand, a new spin reversal method not using current magnetic field is recently theoretically proposed, as disclosed by J. C. Slonczewski, "Current-driven excitation of magnetic multilayers", (1996), J. Magn. Magn. Mater., 159, L1-L7, and was also realized experimentally (Refer, for example, to J. A. Katine, F. J. Albert, R. A. Ruhman, E. B. Myers and D. C. Ralph, "Current-Driven Magnetization Reversal and Spin-Wave Excitations in Co/Cu/Co Pillars", (2000), Phy. Rev. Lett., 84, pp. 3149-3152).

[0009] Said spin reversal method is such that, in a triple layer structure consisting of the first ferromagnetic layer **101**/nonmagnetic metal layer **103**/the second ferromagnetic layer **105** as its principle is illustrated in **FIG. 25**, if the electric current flows from the second ferromagnetic layer **103** to the first ferromagnetic layer **101**, spin polarized electrons are injected from the first ferromagnetic layer **101** via nonmagnetic metal layer **103** to the second ferromagnetic layer **105**, and the spin of the second ferromagnetic layer **105** is reversed. It is called magnetization reversal by spin injection.

[0010] In said spin injection magnetization reversal of triple layer structure, if the spin of the first ferromagnetic layer **101** is assumed to be fixed, and if the spin is injected from the first ferromagnetic layer **101** via nonmagnetic metal layer **103**, then the injected upward spin (majority spin) gives torque to the spin of the second ferromagnetic layer **105**, and arranges said spin in one direction. Therefore, the spins of the first and the second ferromagnetic layer **101** and **105** become parallel. On the other hand, if the electric current flows in reverse direction, and the spin is injected from the second ferromagnetic layer **105** to the first ferromagnetic layer **101**, then the downward spin (minority spin) is reflected at the interface between the first ferromagnetic layer **101** and nonmagnetic metal layer **103**, the reflected spin gives torque to the spin of the second ferromagnetic layer **105**, and tends to arrange said spin in one direction, namely, downward. As a result, the spins of the first and the second ferromagnetic layer **101** and **105** become antiparallel. Consequently, in said spin injection magnetization reversal of triple layer structure, the spins of the first and the second ferromagnetic layer can be made parallel or antiparallel by switching the direction of current.

[0011] In recent years, giant magnetoresistance (GMR) effect devices consisting of multiplayer film of ferromagnetic layer/nonmagnetic metal layer, tunnel magnetoresistance effect devices consisting of ferromagnetic layer/insulating layer/ferromagnetic layer, and ferromagnetic spin tunnel junction (MTJ) devices have been drawing attentions as new magnetic field sensors and non-volatile magnetic random access memory (MRAM) devices.